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Spatial and Temporal Patterns in the Influence of Land Use on Water Quality in Five Portland Area Creeks Representing Differing Levels of Urbanization

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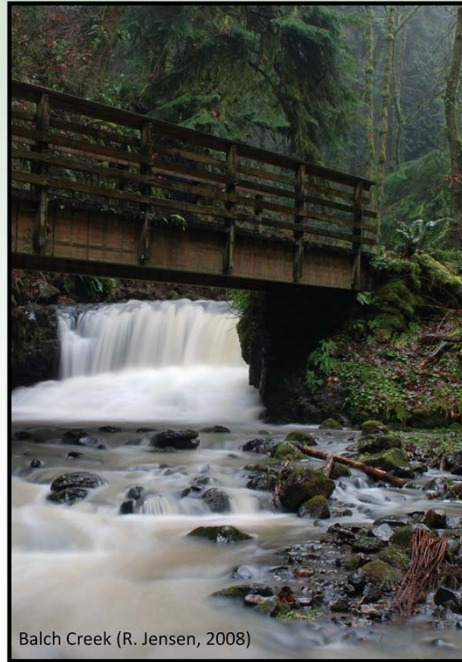
**Spatial and temporal
patterns among multiple
water quality parameters,
precipitation, and land
use in six Portland,
Oregon streams**

*The Oregon Water Conference
May 25th, 2011*

Madeline Steele, Zoe Bonak,
and Heejun Chang
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Portland State
UNIVERSITY



Balch Creek (R. Jensen, 2008)

Zoe and I are master's students in geog at PSU

Started this project in hydrology class, expanded it in the spatial quantitative analysis class.

We're hoping to refine and enhance the project and would love to get your feedback.



Balch Creek (Zoe Bonak, 2010)

Overview

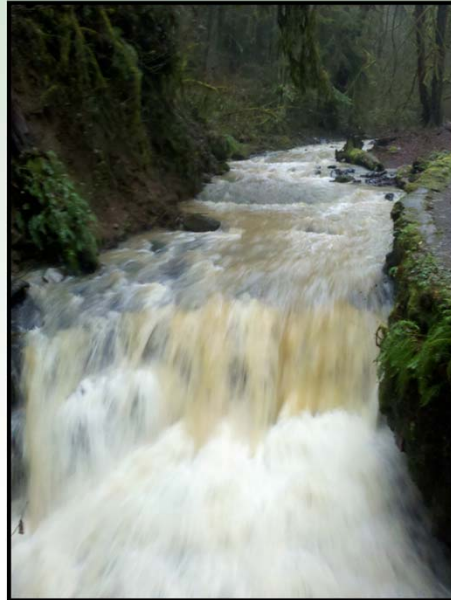
- Introduction
- Research Questions
- Study Area
- Methods
- Selected Results
- Conclusions
- Next steps

Mention that we'd love to get feedback!

Introduction

We are interested in:

- Land use and water quality
- Precipitation and water quality
- Variation among spatial and temporal scales



Balch Creek (Zoe Bonak, 2010)

Talk a little about water quality land use relationship

Citations:

BES Westside Streams Report

Paul and Meyer 2001 (urbanization's damaging effects on waterways, especially by increasing stream temperatures)

Dunne and Leopold 1978 – hydrology “bible”

Wear, et al 1998 – importance of water quality for humans

Research Questions:

- Are there water quality trends in Portland area streams?
 - Do they relate to land use?
 - Do Green Streets improve water quality?
- How are land use classes correlated with impaired water quality?
 - How do these effects vary with scale/distance?
- Are antecedent moisture conditions correlated to water quality?
 - Which length of time has the strongest effect?



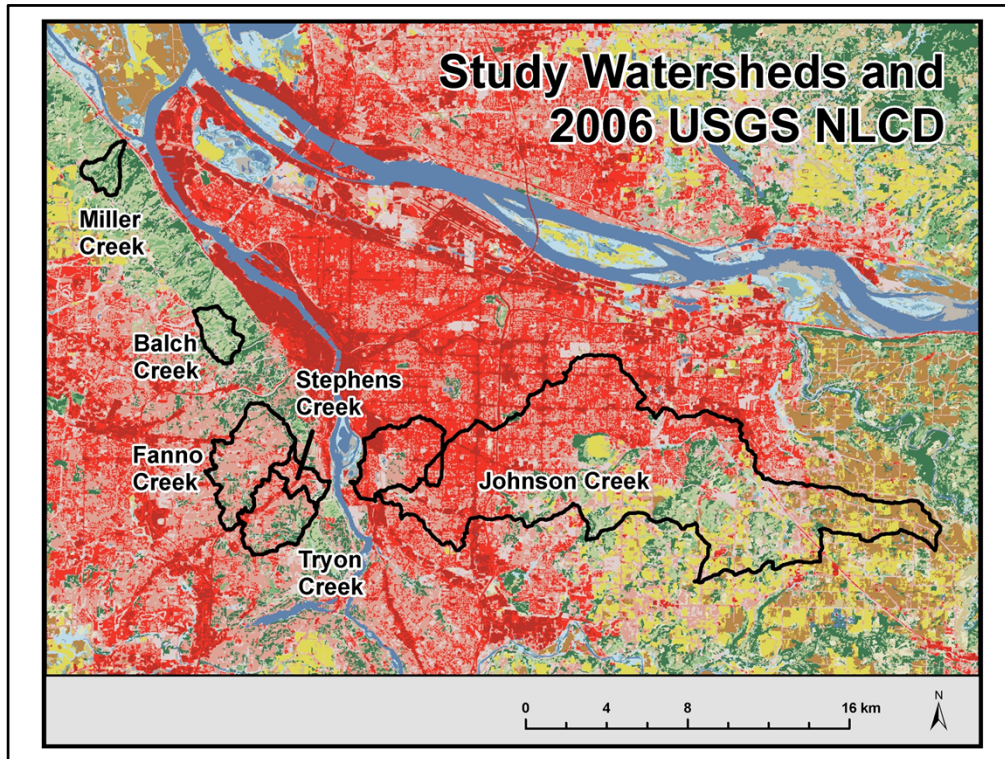
Have these questions been approached before?

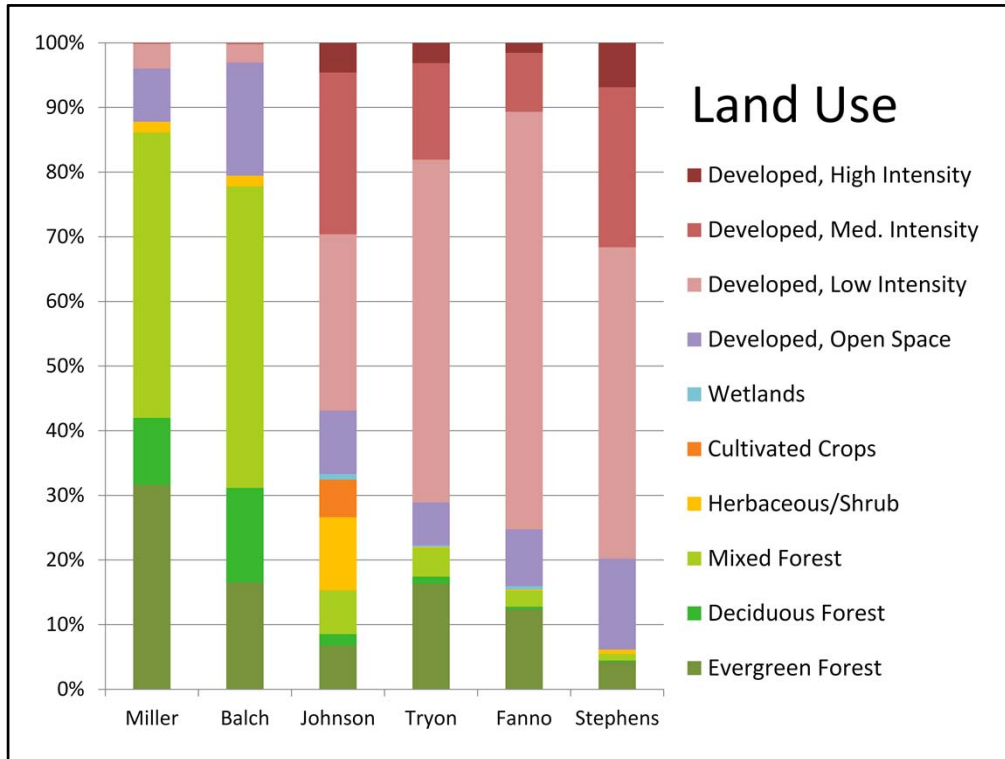


Balch Creek (Zoe Bonak, 2010)

Site Selection

- Wanted watersheds with variety of land cover
- Water quality data requirements:
 - 10 years for temporal
 - 5 years for spatial
- Selected 13 sites for temporal analysis
 - 4 analytes each
- 15 sites for spatial analysis
 - 6 analytes each





Data Sources

- Monthly Water quality grab samples
 - City of Portland Bureau of Environmental Services (BES)
- GIS
 - USGS 2006 Land Cover
 - Portland Metro RLIS
 - Portland BES Green Streets 2011
- Precipitation
 - Portland HYDRA network (USGS)

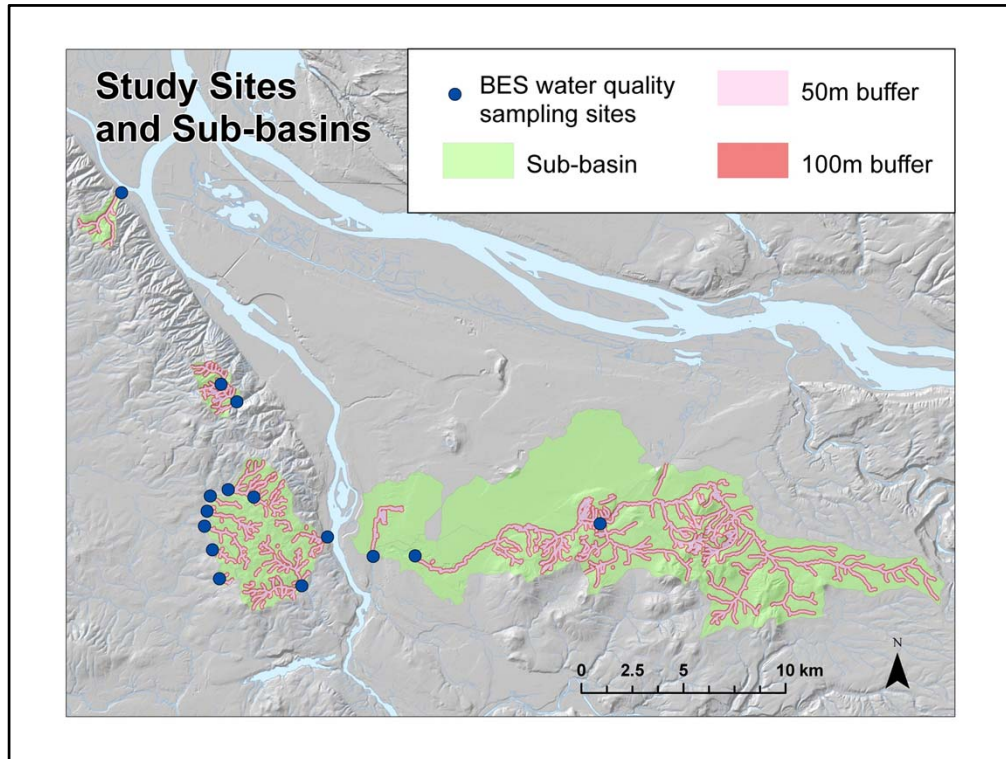
Spatial and temporal analysis

Spatial analysis only

	Analyte	Method	MRL	Units
Cond	Conductivity, Specific	SM 2510 B	1.00	μmhos/cm
DO	Dissolved Oxygen	SM 4500–O G	0.10	mg/L
Temp	Temperature	SM 2550 B	0.10	deg C
TP	Phosphorus, Total	EPA 365.4	0.03	mg/L
TSS	Solids, Total Suspended	SM 2540 D	1.00	mg/L
N	Nitrate	EPA 300.0	0.10	mg/L

Add abbreviations column to this slide

Quickly explain logic for selecting these parameters



Say that we delineated these with a 10–m DEM (USGS)
REDO without hillshade, and including subwatershed boundaries.

Land Use / Land Cover Metrics

- Population Density
(persons / km²)
- Street Density
(km / km²)
- Percent Forested
- Percent Agriculture
- Percent Low-Density
Development
- Percent Medium/High Density
Development
- Green Street Feature Density



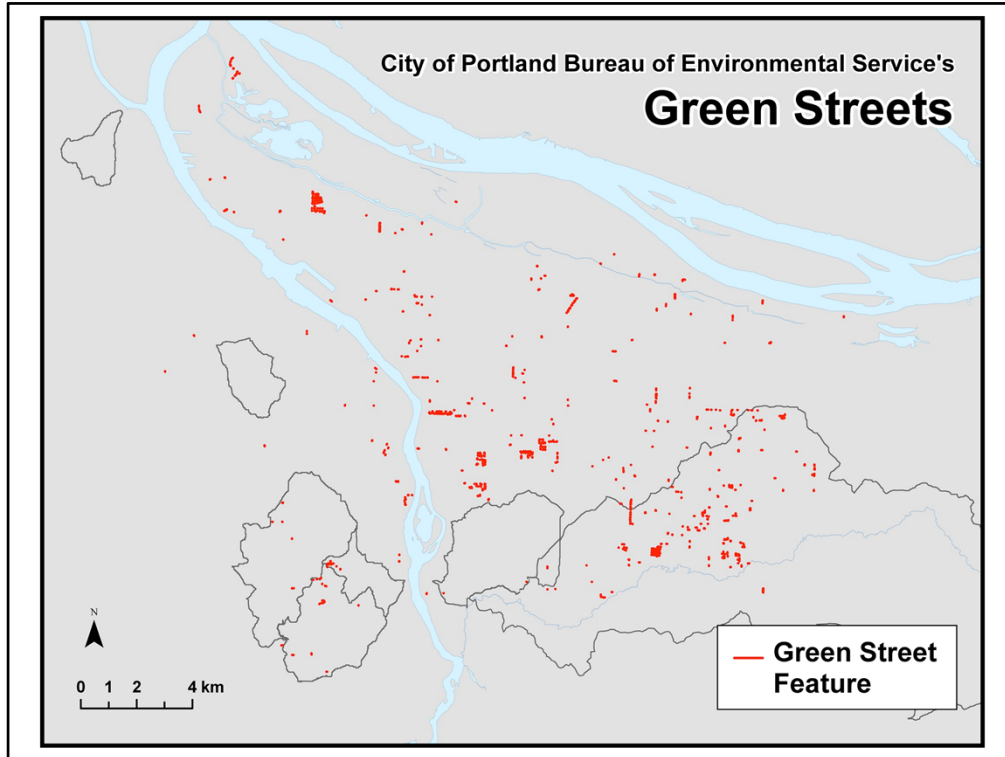
Fanno Creek (Tualatin River Keepers, 2009)

Green Streets

According to BES GIS data:

- 3 before 2000
- 85 before Jul. 2005
- 903 before Oct. 2010





Precipitation Data

- Geocode HYDRA station addresses
- Found HYDRA station closest to water quality sampling site
- For each measurement date, calculated same day precipitation (mm), as well as 3-, 5-, and 7-day cumulative precipitation values

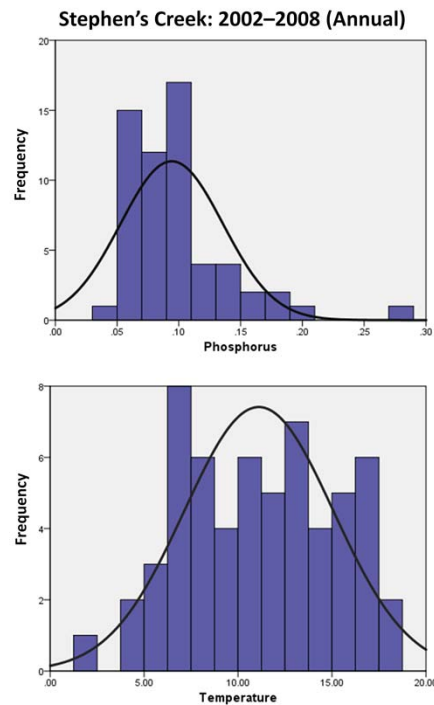


Johnson Creek (KATU, 2011)

*Hamilton and Luffman 2009

Statistical Analyses

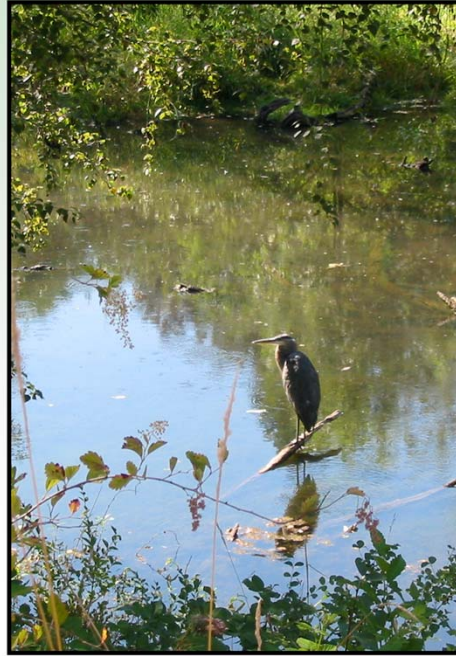
- Methods used:
 - Descriptives/visuals (box-whisker plots, histograms)
 - Spearman's Rank Correlation Coefficient (ρ)
 - Seasonal Kendall Test
- Software:
 - ArcGIS v. 10
 - SPSS v. 19
 - Excel v. 2010
 - MATLAB



Burkey 2009 ; found that much of the data was non-normal. Decided to adopt a non-parametric approach.

Results Overview

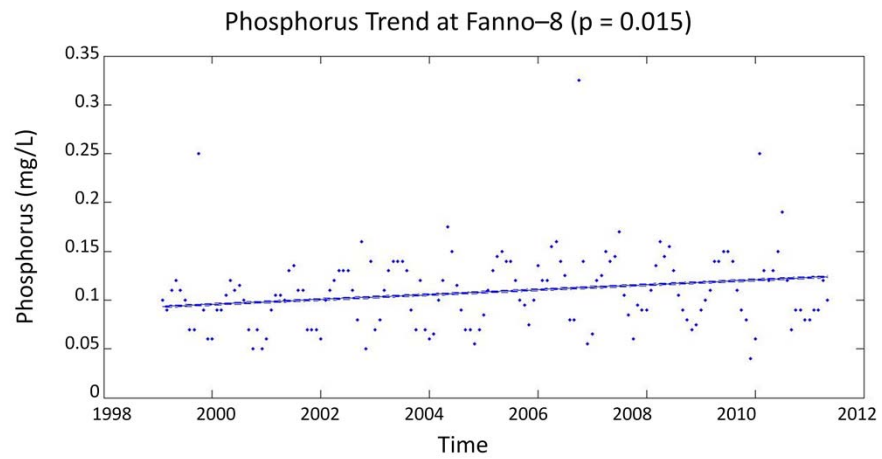
- Seasonal Kendall trend analysis outputs
- Selected correlations between land cover metrics and analytes
- Selected correlations between antecedent moisture conditions and analytes

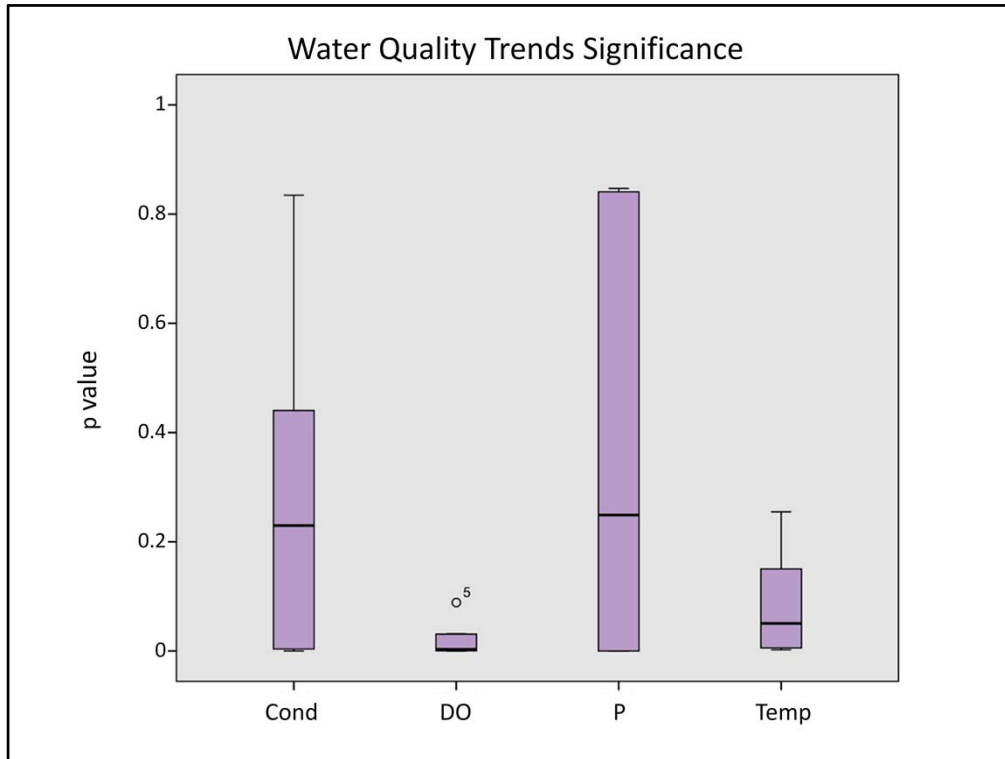


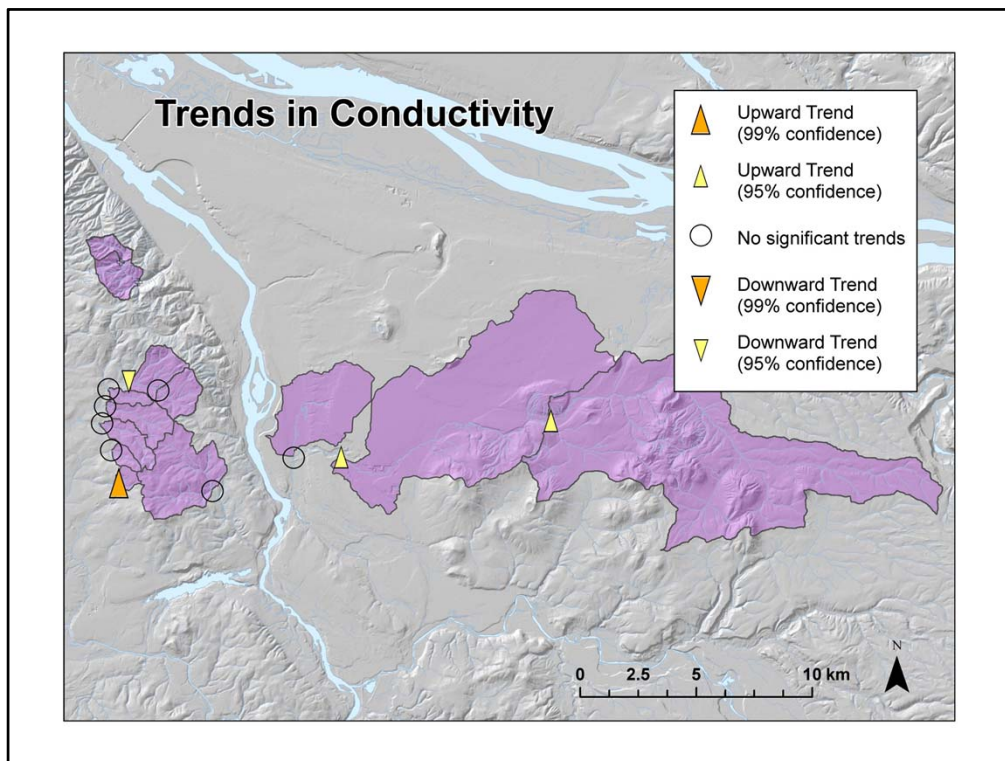
Fanno Creek (Penny Sunlove, 2010)

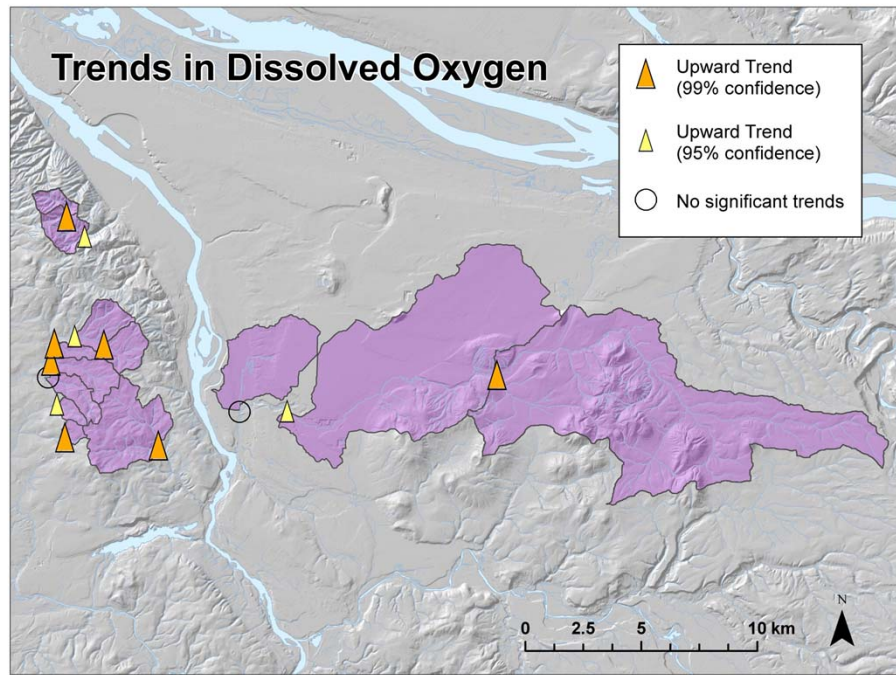
Seasonal Kendall Results

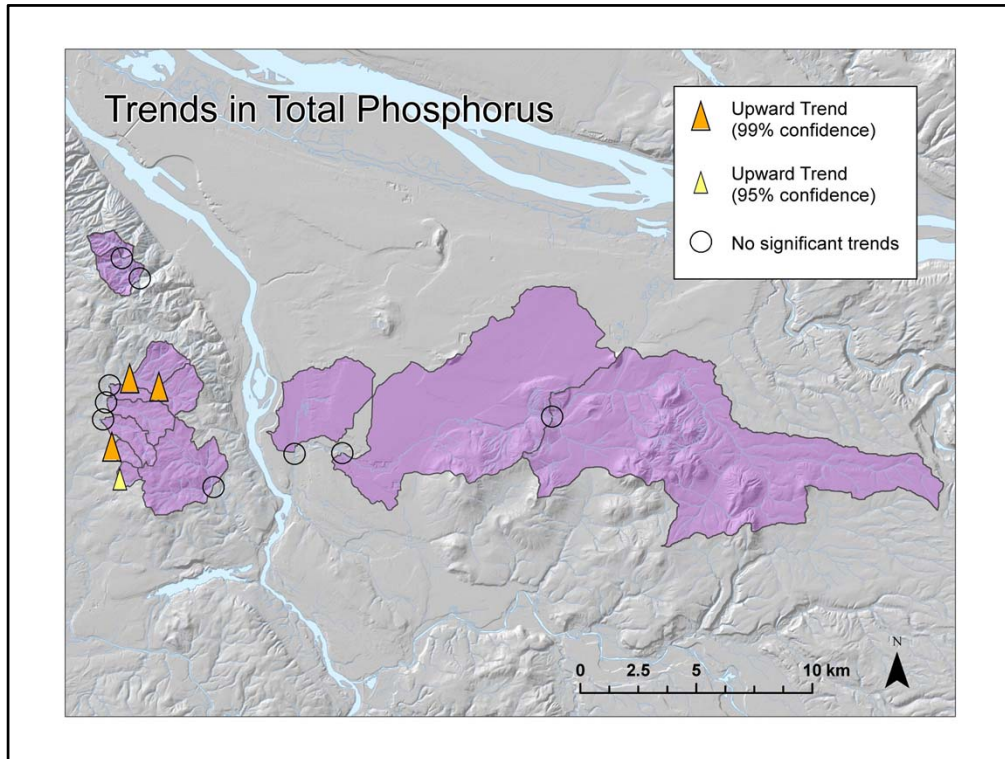
Example Output:



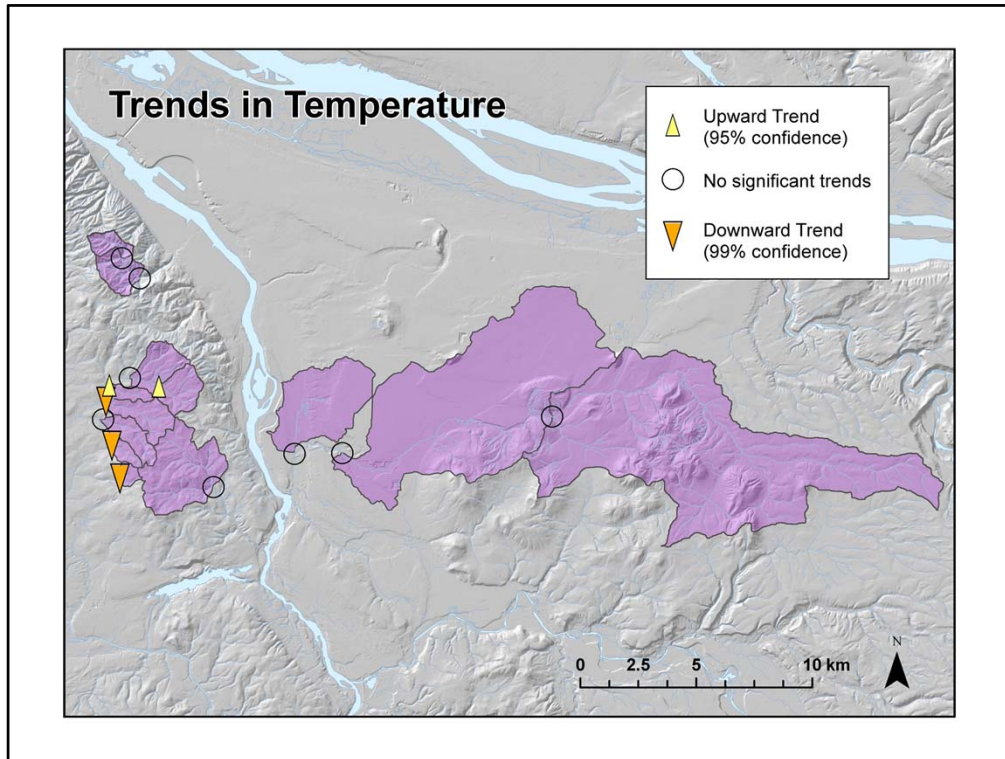








Make the title bold, if there is time.



Spearman's' correlations between SC and metrics at three spatial and temporal scales

Sub-basin	Annual	Dry	Wet	100m Buffer	Annual	Dry	Wet	50m Buffer	Annual	Dry	Wet
Population Density	.40	.36	.39	Population Density	.63*	.56*	.63*	Population Density	.66**	.61*	.66**
Street Density	.70**	.68**	.71**	Street Density	.63*	.62*	.67**	Street Density	.69**	.67**	.73**
% Forested	-.56*	-.53*	-.59*	% Forested	-.54*	-.50	-.54*	% Forested	-.57*	-.54*	-.58*
% Agriculture	-.59*	-.55*	-.59*	% Agriculture	-.59*	-.55*	-.59*	% Agriculture	-.59*	-.55*	-.59*
% Low Density Developed	.49	.45	.51	% Low Density Developed	.57*	.53*	.60*	% Low Density Developed	.62*	.59*	.64*
% High Density Developed	.25	.25	.28	% High Density Developed	.43	.42	.45	% High Density Developed	.45	.44	.47

<i>strong correlation</i>	<i>** = significant at the 0.01 level</i>
<i>moderate correlation</i>	<i>* = significant at the 0.05 level</i>

Specific Conductivity:

Street density (annual–subbasin, wet–50m)

- Impervious surface runoff contributing ions to the stream

Spearman's' correlations between TSS and metrics at three spatial and temporal scales

Sub-basin	Annual	Dry	Wet	100m Buffer	Annual	Dry	Wet	50m Buffer	Annual	Dry	Wet
Population Density	.21	.78**	-.14	Population Density	.03	.76**	-.33	Population Density	.03	.79**	-.35
Street Density	-.23	.25	-.35	Street Density	-.17	.53*	-.37	Street Density	-.13	.67**	-.38
% Forested	.23	-.24	.27	% Forested	.21	-.22	.27	% Forested	.31	-.21	.35
% Agriculture	-.50	-.59*	-.13	% Agriculture	-.50	-.59*	-.13	% Agriculture	-.50	-.59*	-.13
% Low Density Developed	.21	.71**	.00	% Low Density Developed	.04	.65**	-.16	% Low Density Developed	-.07	.56*	-.26
% High Density Developed	-.41	-.25	-.29	% High Density Developed	-.16	.06	-.10	% High Density Developed	-.14	.08	-.10

strong correlation	** = significant at the 0.01 level
moderate correlation	* = significant at the 0.05 level

TSS:

Population density (dry-subbasin, dry-100m, dry-50m)

%LowDenDev (dry-subbasin)

– Dry season storm events – large pulses of sediment flowing off impervious surfaces and dry soils

Because the Portland area does not typically receive much rain during the summer months, any precipitation event is likely to have a flushing effect on the landscape because soil is not in a state of constant saturation. Stream flow volume is lower and less able to dilute sediment in the dry season. Additionally, construction and other major soil disturbances are more likely to take place in the dry season.

Spearman's' correlations between Temperature and metrics at three spatial and temporal scales

Sub-basin	Annual	Dry	Wet	100m Buffer	Annual	Dry	Wet	50m Buffer	Annual	Dry	Wet
Population Density	-.40	-.67**	.18	Population Density	-.11	-.42	.42	Population Density	-.08	-.39	.45
Street Density	.33	.49	.55*	Street Density	.17	.16	.52*	Street Density	.11	.01	.58*
% Forested	-.66**	-.63*	-.65**	% Forested	-.65**	-.66**	-.67**	% Forested	-.62*	-.66**	-.66**
% Agriculture	.50	.50	-.13	% Agriculture	.50	.50	-.13	% Agriculture	.50	.50	-.14
% Low Density Developed	.34	.17	.69**	% Low Density Developed	.35	.23	.72**	% Low Density Developed	.30	.26	.67**
% High Density Developed	.65**	.74**	.36	% High Density Developed	.57*	.74**	.49	% High Density Developed	.53*	.71**	.50

strong correlation

**** = significant at the 0.01 level**

moderate correlation

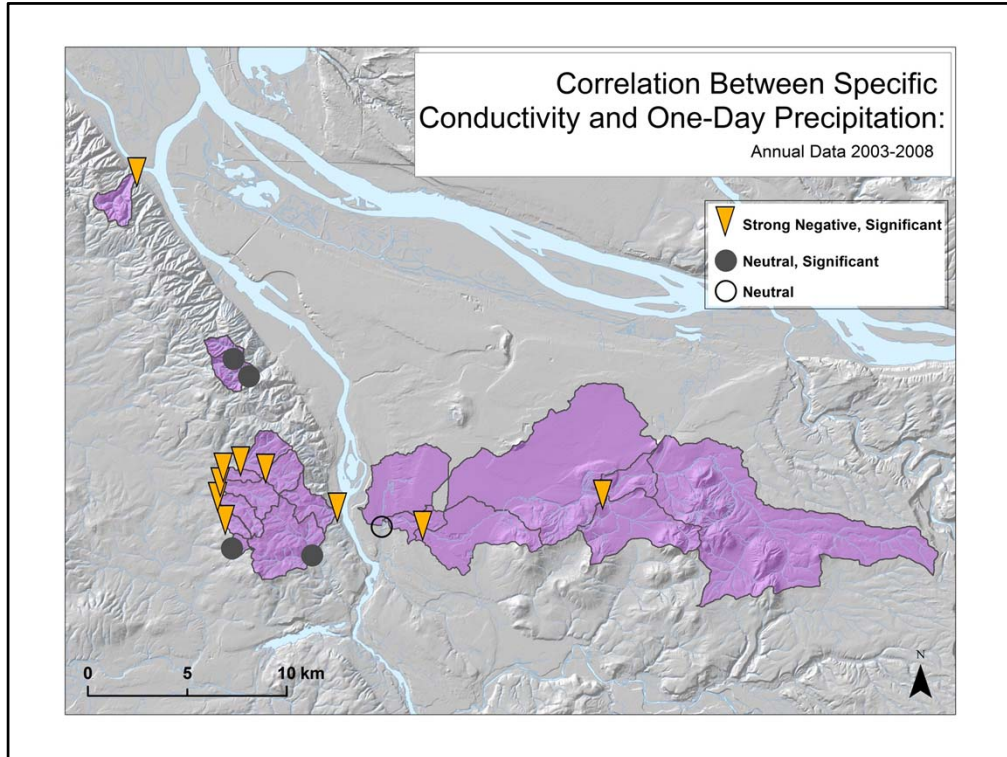
*** = significant at the 0.05 level**

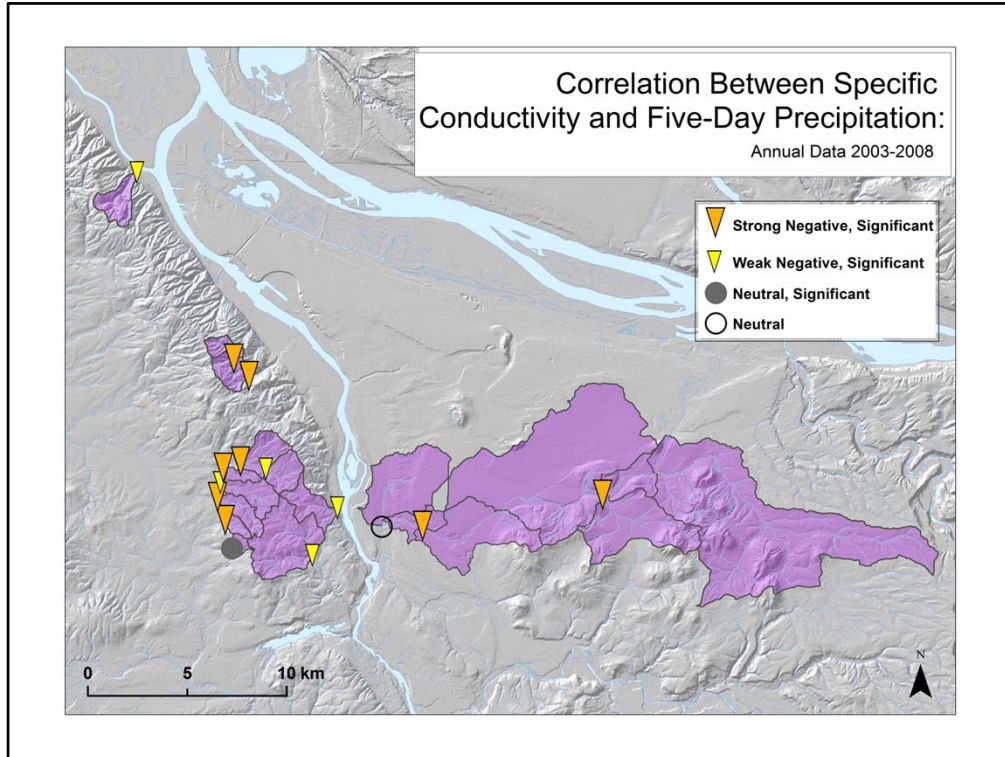
Temperature:

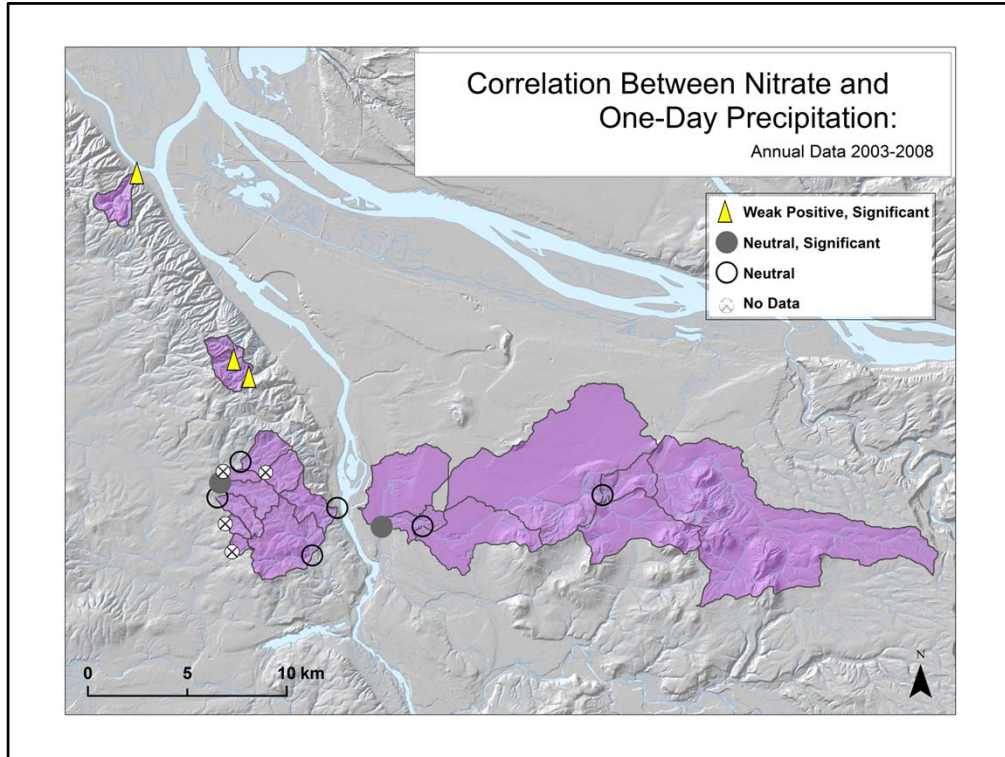
%HighDenDev (dry-subbasin, dry-100m, dry-50m)

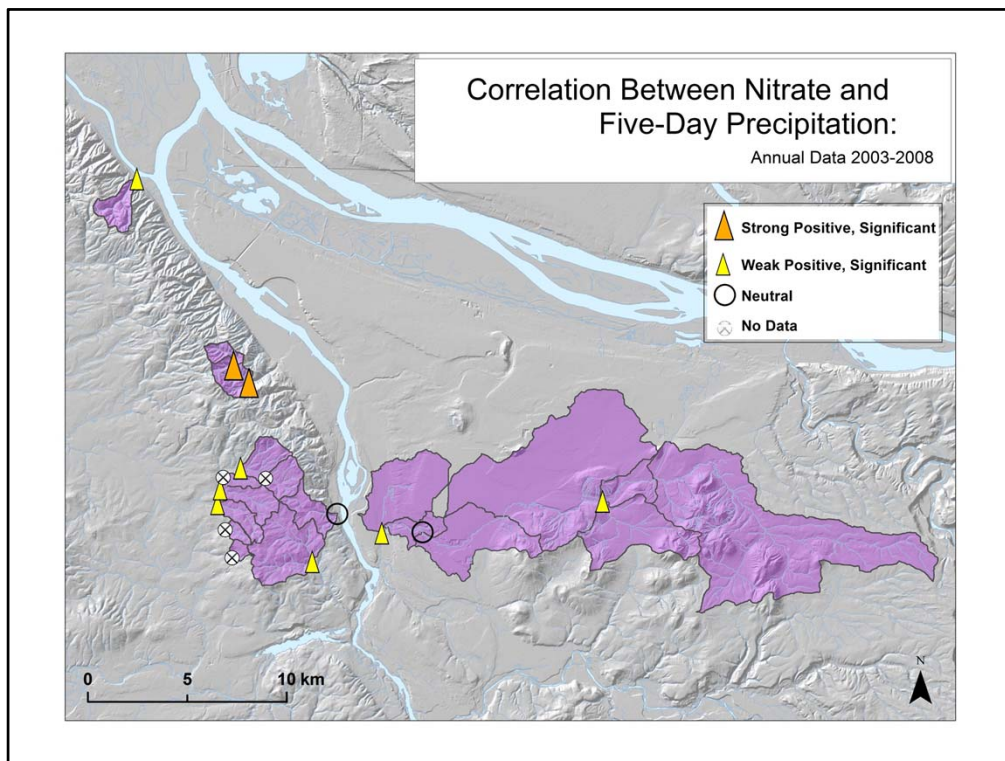
%LowDenDev (wet-100m)

- Urban heat island effect
- Less riparian shading (?)
- Thermal pollution from impervious surface runoff(?)









Trend Analysis Summary

- DO improved significantly
- T improved, but less significantly
- Only 5 of the 49 trend tests showed significant WQ declines, all in Fanno
- No significant correlation between WQ trends and land use metric changes



Fanno Creek (David S., 2011)

suggest that water quality can continue to deteriorate in highly urban basins even after almost all development has been completed.

Spatial Analysis Summary

- SC showed strong, significant correlations with street density during the wet season
 - Suggests that road runoff is regularly washed into many Portland area streams during the wet season
- TSS showed strong, significant correlations to population density in the dry season
 - Likely caused by the flushing of built up sediment from impervious areas
- T showed strong, significant correlation to high density development during the dry season
 - Likely caused by lack of riparian shading or thermal pollution from runoff from heated impervious surfaces
- No correlations between Green Streets point density and WQ

SC correlations strong and sig. at subbasin and buffer

TSS strong and sig. at all three scales

Need a better way to quantify BMPs

Antecedent Precip. Summary

- Spatially heterogeneous results
- Only Balch Creek shows strong correlations between N and 5- and 7-day antecedent precip.
 - Suggests more N in Balch comes from subsurface or groundwater flow
- Only Miller shows strong correlations between TSS and 1-, 3-, and 5-day antecedent precip.
 - Localized geomorphic variation?
- SC alone was showed consistent pattern
 - Strongly correlated to 3-, 5-, and 7-day antecedent precip. at many sites

in both seasons, and annually

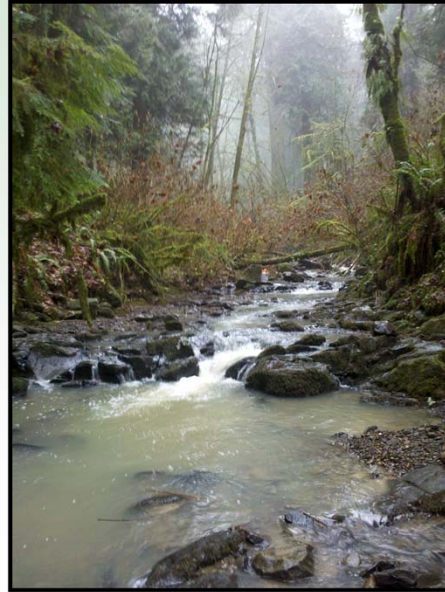
Some Limitations of Data and Analyses

- Small number of sampling sites
- Coarse resolution of some GIS data layers
 - Example: 50m riparian zone with 30m cells (USGS LULC 2006)
- Non-normal distribution of data prevents parametric analyses
- Soil data, geology, and septic system age were not considered

Expand??

Next Steps

- Incorporate data on septic systems and stream restoration activities
- Use more water quality parameters, such as pH
- Use more metrics
 - Percent impervious surface
 - Slope
 - Geology
- Correct for climatic influences on water temperature and dissolved oxygen
- Use higher resolution LULC layer from Inst. For Natural Resources



Balch Creek (Zoe Bonak, 2010)

Thanks to Zoe, Heejun, and the Portland BES!

We would love to hear your feedback!

References

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Add any references that you plan to mention